Review result of "On the movement of atmospheric blocking systems and the associated temperature responses" by Mourik et al."

Overall recommendation: Major revision

I have read this revised manuscript in detail. It seems that the authors only made a minor revision and didn't answer my major issues. Thus, I am not satisfied for the author's revision, even though this manuscript has been improved in part. In my initial review, I have pointed out that the author's 2D Cell-tracking Algorithm used to identify the zonal propagation velocity of atmospheric blocking is likely incorrect. Unfortunately, the authors did not present any responses to my issue in this new revised version. Because the 2D Cell-tracking Algorithm failed to identify the zonal propagation speed of atmospheric blocking, the author's conclusion about the propagation speed of atmospheric blocking is confusing and not solid. Based on this, I recommend that a major revision of this manuscript is still needed.

Major comments:

(1) In my initial review, I have pointed out that the two-dimensional (2D) Cell-tracking Algorithm as a Lagrangian method cannot correctly identify the zonal propagation speed of atmospheric blocking. Such a method will lead to a misleading conclusion. Unfortunately, the authors did not present any responses in the revised manuscript. Below, I again give my issues:

In the Data and Method section (lines 130-144 in the original manuscript), the authors tried to use the two-dimensional (2D) Cell-tracking Algorithm to calculate the zonal propagation velocity of atmospheric blocks. However, I think that such a 2D Cell-tracking Algorithm fails to identify the zonal propagation velocity of atmospheric blocking because this 2D Cell-tracking algorithm cannot differentiate the group velocity and zonal phase speed or propagation velocity of the blocking anomaly in the geopotential height fields in the form of

$\psi_B = B\sqrt{\frac{2}{L_y}}\exp[i(kx-\omega t)]\sin(my)+cc$ (Luo et al. 2019), where cc denotes the complex conjugate of its preceding term, L_y is the width of beta channel and B(x,t) is the complex blocking envelope amplitude and the time-longitude variation of absolute B(x,t) or $|B|$ denotes the group velocity of the blocking anomaly ψ_B with zonal wavenumber k, $C_p=\omega/k$ is the zonal propagation velocity of the linear blocking anomaly in a linear theory framework. In a nonlinear theory framework, the zonal propagation velocity of the blocking anomaly is $C_{NP}=U-\frac{\mathrm{PV_y}}{k^2+m^2+F}-\frac{\delta_N M_0^2}{2k\mathrm{PV_y}}$, where U is the basic zonal wind, PV_y is the meridional gradient of background potential vorticity and M_0 is the blocking amplitude or intensity. If the authors calculate the movement speed of ψ_B by tracking the maximum or minimum intensity of ψ_B, this movement speed cannot represent the zonal propagation velocity of atmospheric blocking. Thus, I do not think that the results based on the 2D Cell-tracking algorithm are correct. Of course, it is also difficult to compute the group velocity and zonal propagation velocity of atmospheric blocking using the 2D Cell-tracking algorithm. Please also see Zimin et al. (2003, 2006) about how to calculate the group velocity and zonal propagation velocity of Rossby wave packet (atmospheric blocking).

Based on the blocking theory, I think that the 2D Cell-tracking algorithm the authors used are not correct. The authors should at least provide evidence to confirm if the author's method is correct. For example, in a revised version the authors should at least discuss some issues: For example, the authors should discuss whether the 2D Cell-tracking algorithm is suitable for identifying the zonal propagation speed of atmospheric blocking。Is whether it consistent with the previous blocking theory (i.e., Luo et al. 2019) and the previous diagnostic methods (i.e., Zimin et al. 2003, 2006). I suggest that the authors should calculate the zonal movement speeds of quasi-stationary, retrograde and eastward-moving blocking events by plotting the time-longitude Hovmoller diagrams of the composite daily Z500 anomalies for each type of blocking events and then further compare them with the results obtained from 2D Cell-tracking algorithm. Such a comparison can confirm whether the 2D Cell-tracking algorithm is correct.

(2) How to calculate the zonal phase speed of blocking events

When blocking events in a certain region are classified into three types: Quasi-stationary, retrograde and eastward-travelling blocking events, the authors may perform a daily composite to the daily evolution of the Z500 (t, x, y) anomaly for each type of blocking events. The authors can calculate the zonal phase speed of blocking for each type of blocking event if the authors plot the time-longitude Hovmoller diagram of the composite daily Z500 (t, x, y) at a fixed latitude y. However, when the authors used the 2D Cell-tracking algorithm to calculate the movement speed by tracking the maximum or minimum value of daily Z500 (t, x,y), the movement speed obtained by the authors is not identical to the zonal phase speed of blocking.

(3) Whether atmospheric blocking undergoes retrogression, westward or eastward movement depends on the background zonal wind U, PV_y and blocking amplitude or intensity in terms of $C_{NP} = U - \frac{PV_y}{k^2 + m^2 + F} - \frac{\delta_N M_0^2}{2kPV_y}$ (Luo et al. 2019). When blocking intensity or amplitude is larger or U or PVy is smaller, atmospheric blocking exhibits a westward movement. In particular, atmospheric blocking with a large zonal size often shows a retrogression because it has generally a large amplitude or intensity.

However, the 2D Cell-tracking algorithm seems to give confused results. For example, in Table 1, it seems that blocking events with large size and intensity move more eastward with a large phase speed. This is very confusing. I suggest that the authors should divide blocking events in winter or summer into three cases: Stationary, retrogression and eastward movement. Then, the authors should calculate the event number, size, intensity and phase speed of the three types of blocking events in winter or summer and further discuss their impacts on local weathers. The authors may find that retrograde blocking events will have larger size (zonal scale), larger intensity, and longer lifetime, which can be more stationary and eastward-travelling if the upstream basic zonal wind is particularly strong (Zhang and Luo 2020). In contrast, the eastward-traveling blocking events will generally have lower intensity, smaller size and shorter lifetime. The authors should read in detail the theoretical papers of Luo et al. (2019) and Zhang and Luo (2020). They have discussed in detail the relationship among the blocking size, intensity and movement as well as their linkages to the background conditions and their impacts.

(4) Please clearly give the definition of the blocking duration. In fact, the duration of atmospheric blocking has different definitions. For example, the persistent time of blocking anomaly with amplitude larger than a threshold in a given domain may be defined as a local duration. This local duration is not equivalent to the lifetime of blocking when the blocking moves in the west-east direction. Clearly, the local duration and lifetime of blocking events are different. It seems that the local duration of the blocking events is more important for the local weather extremes than its lifetime unless the blocking is stationary.

Minor issues are not further shown here.

References:

Luo, D., et al., 2019: A nonlinear theory of atmospheric blocking: A potential vorticity gradient view. J. Atmos. Sci., 76, 2399-2427.

Zimin, A. V., I. Szunyogh, D. J. Patil, B. R. Hunt, and E. Ott, 2003: Extracting envelopes of Rossby wave packets. Mon. Wea. Rev., 131, 1011–1017.

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